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Kato et al.

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(54) **ROTARY ELECTRIC MACHINE WITH POWER CONVERTER**

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H02K 9/22 (2006.01)

(52) **U.S. Cl.**
CPC ***H02K 11/0073*** (2013.01); ***H02K 9/22*** (2013.01); ***H02K 11/0015*** (2013.01)

(58) **Field of Classification Search**
USPC .... 310/68 D, 68 R
See application file for complete search history.

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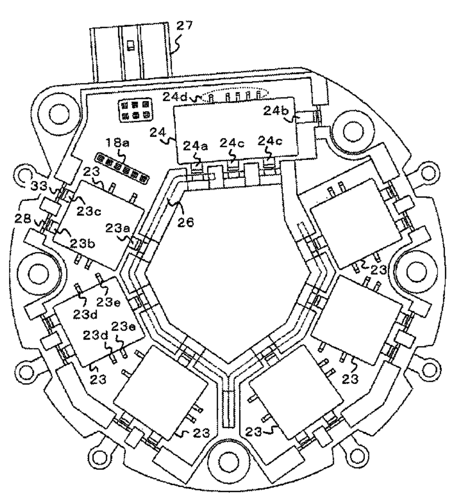
(57) **ABSTRACT**

A rotary electric machine with a power converter includes: a stator that has stator windings; a rotor that has a rotor winding; a rotational position detecting sensor that outputs a rotational position signal of the rotor; a case that contains the stator and the rotor; a field module that is connected to the rotor winding; power modules, each of which is connected to each of the stator windings and has a current detector, a first switching element, and a second switching element; a heat sink fixed to the field module and the power modules; and a control substrate that outputs control signals to the field module and the power modules based on the rotational position signal from the rotational position detecting sensor. The first switching element is connected in series to the second switching element; and the current detector and both switching element are molded with insulating resin.

5 Claims, 7 Drawing Sheets



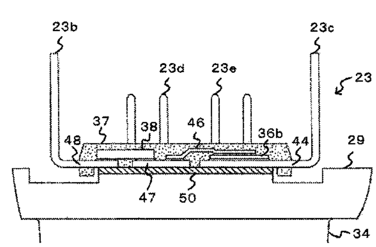


Fig. 1

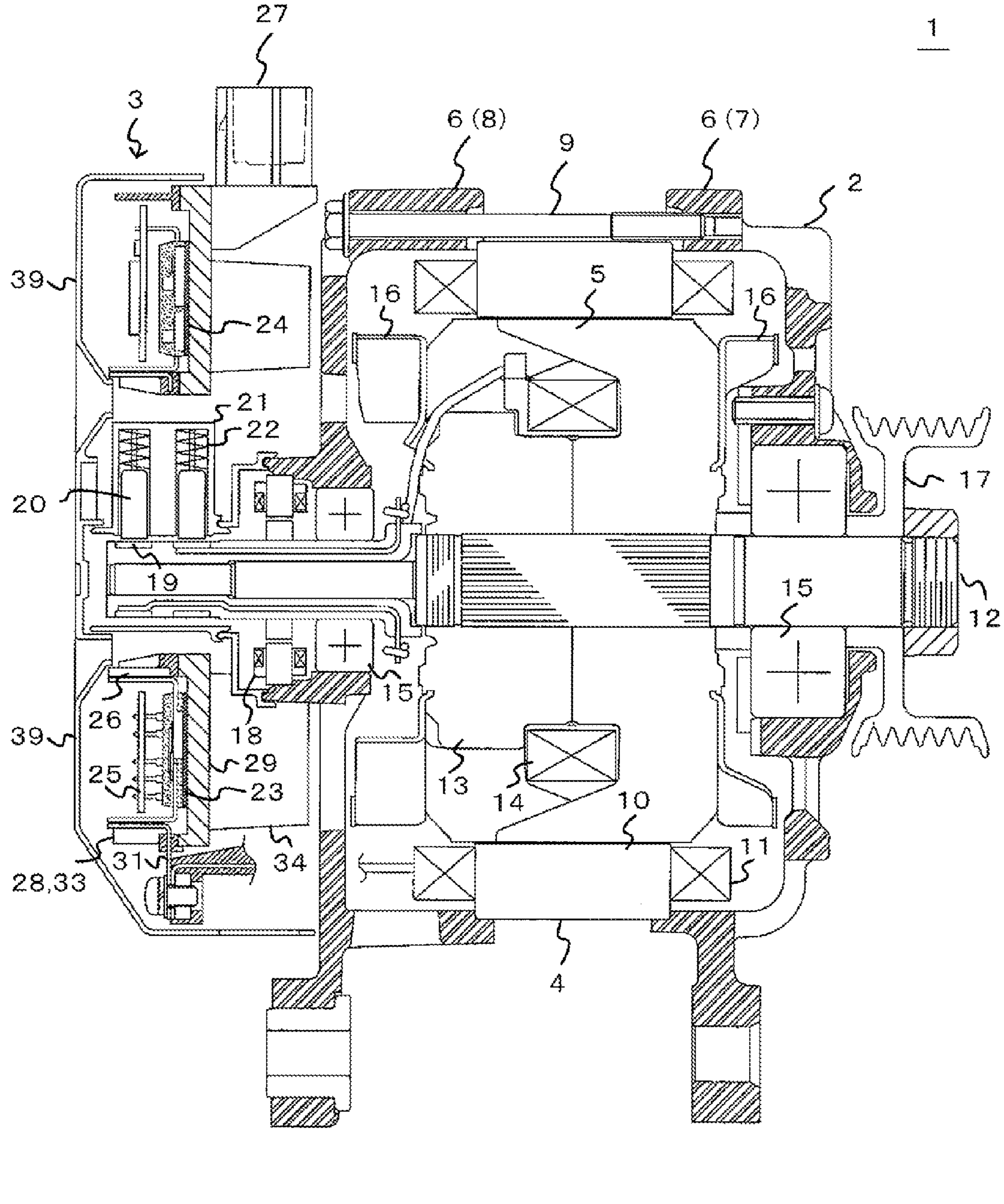

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Fig. 2

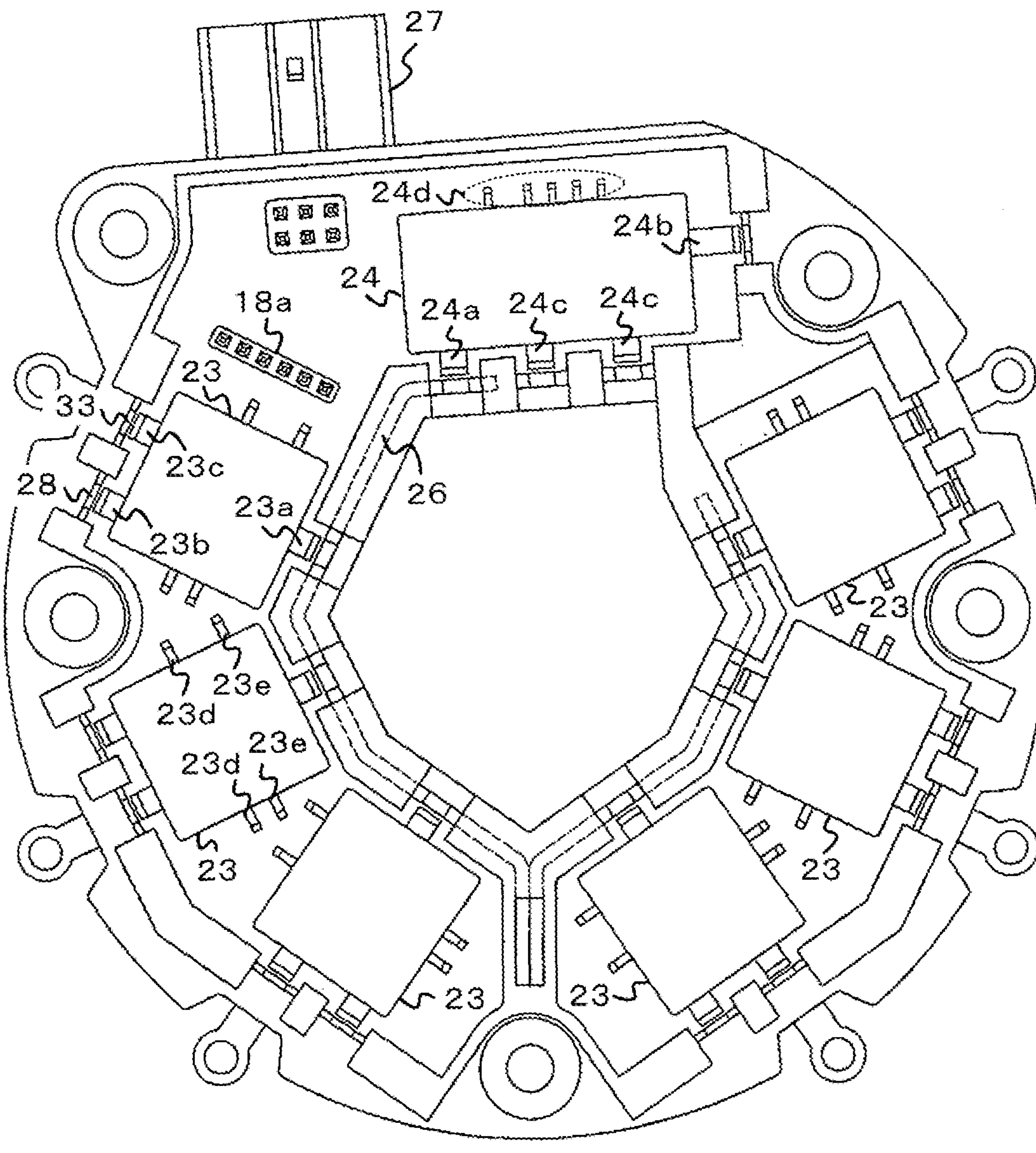
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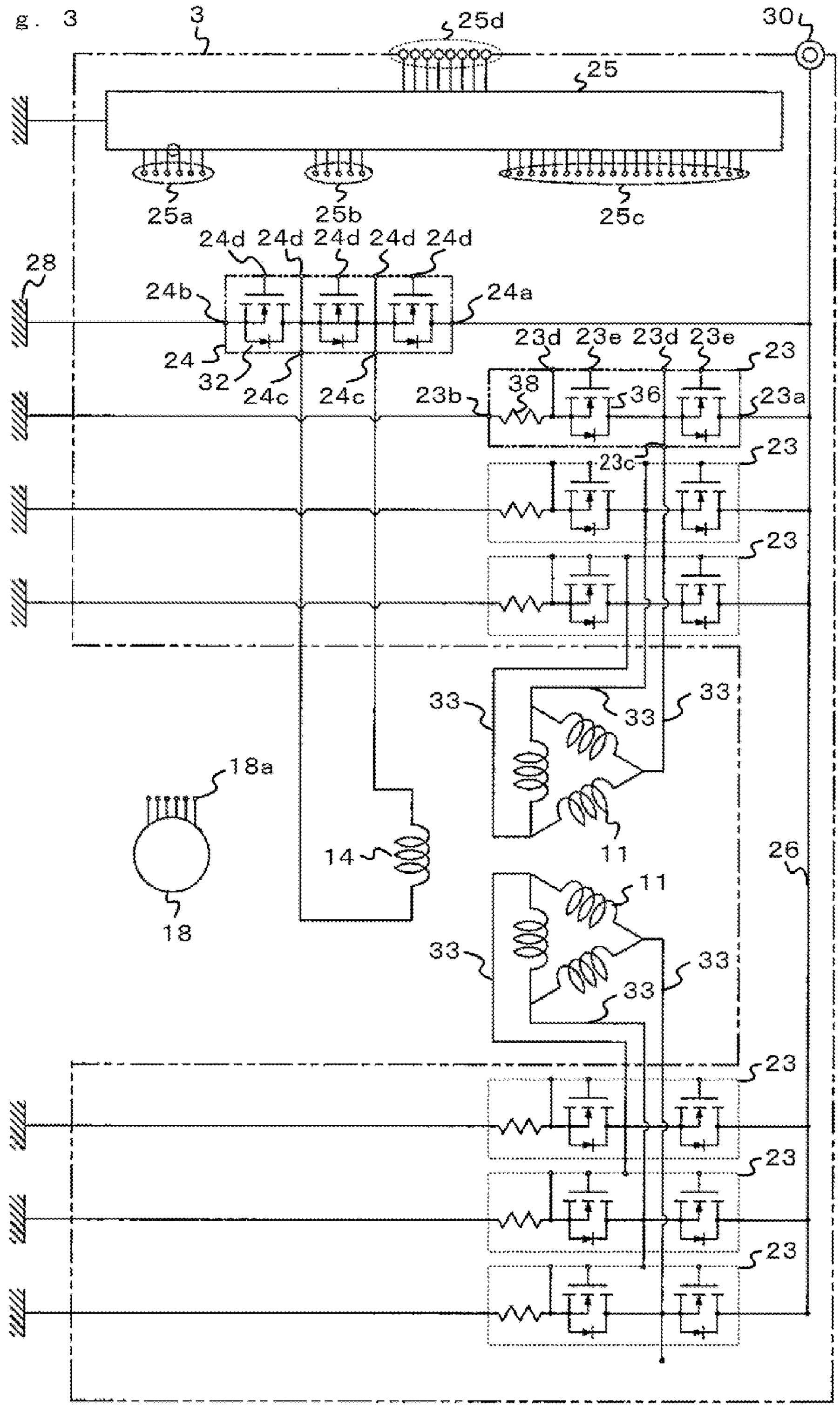
Fig. 3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23b
23a
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18a
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Fig. 4

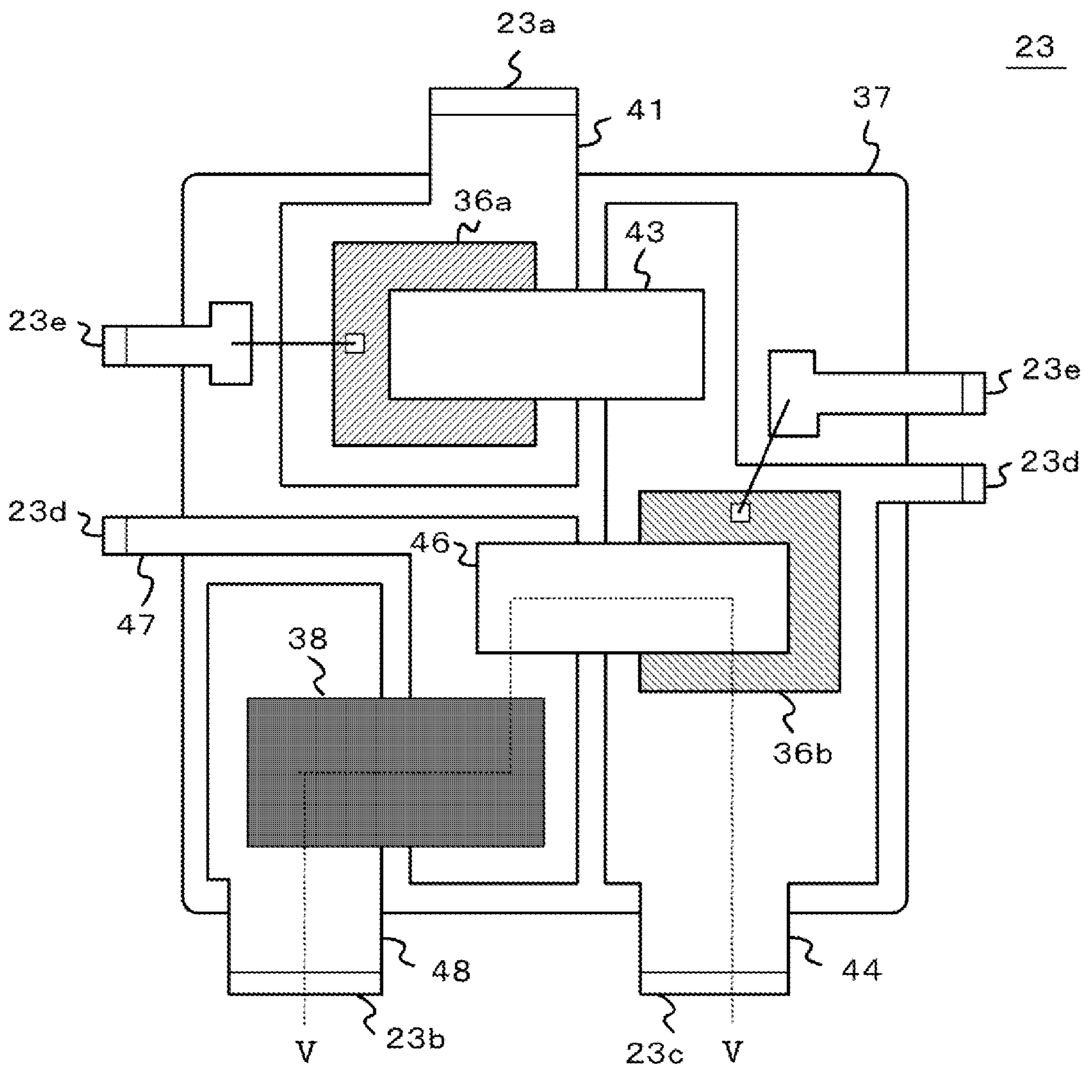
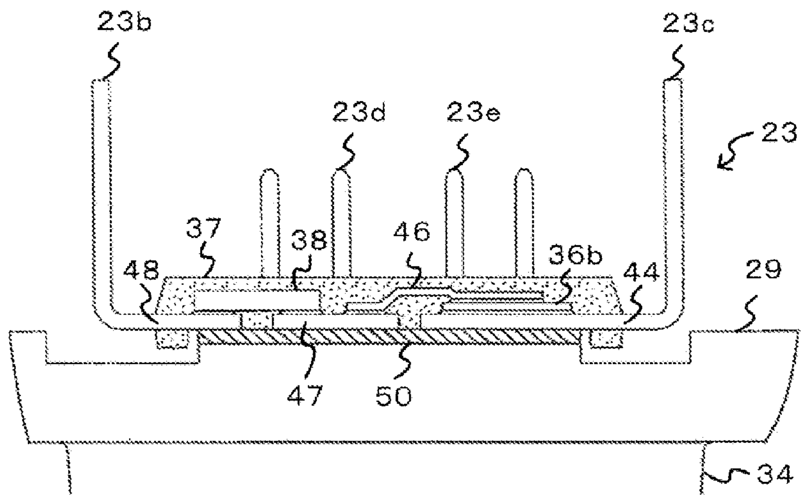


Fig. 5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36b
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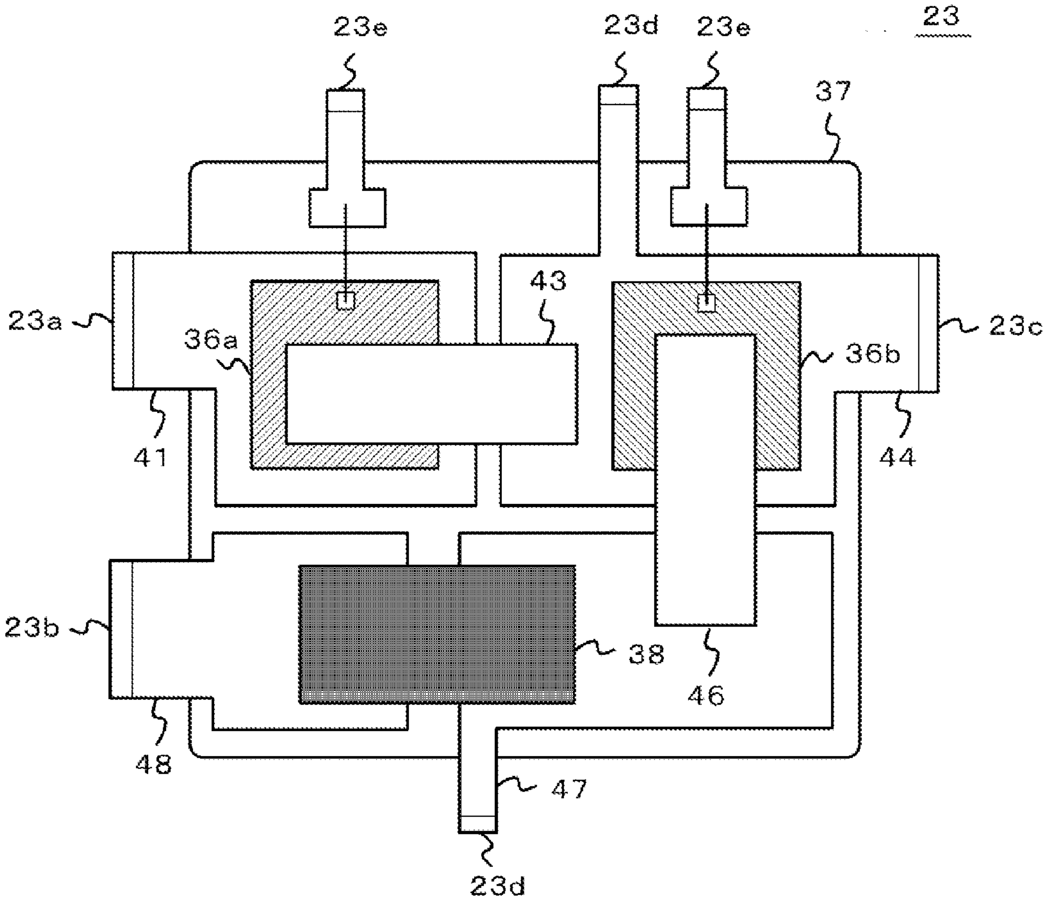
Fig. 6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23d

Fig. 7

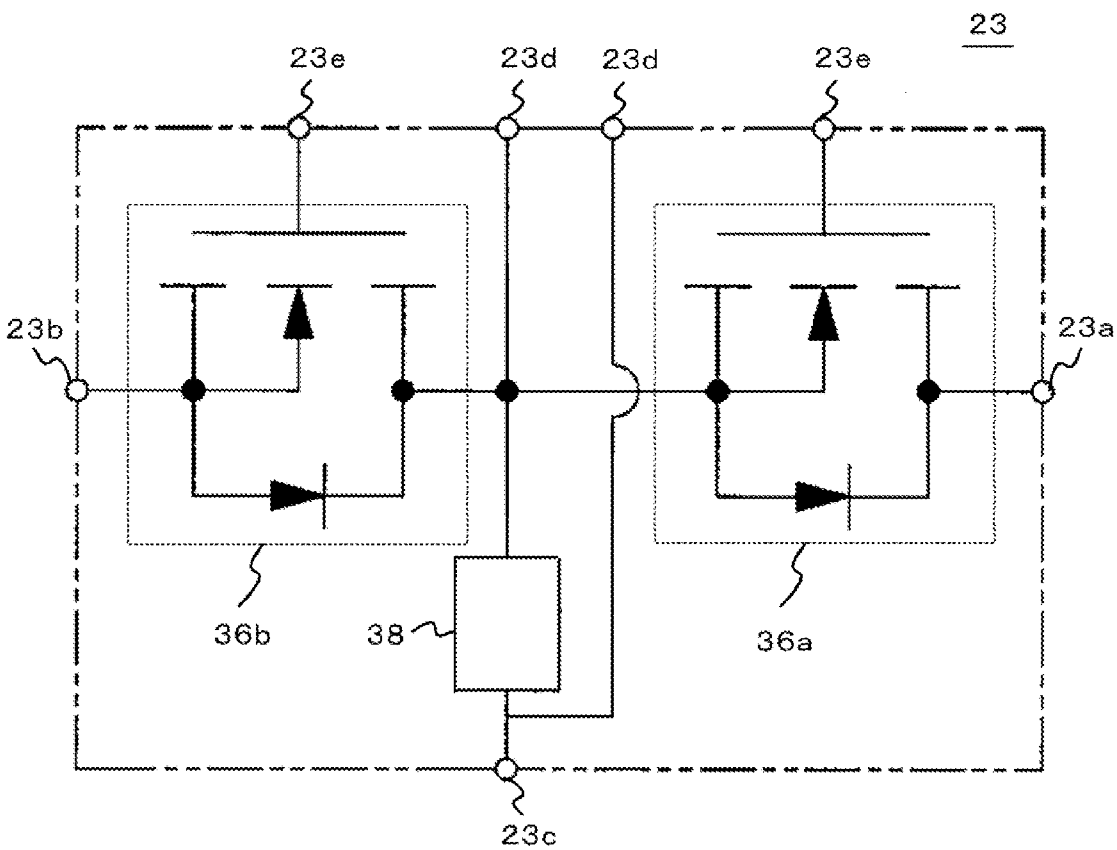
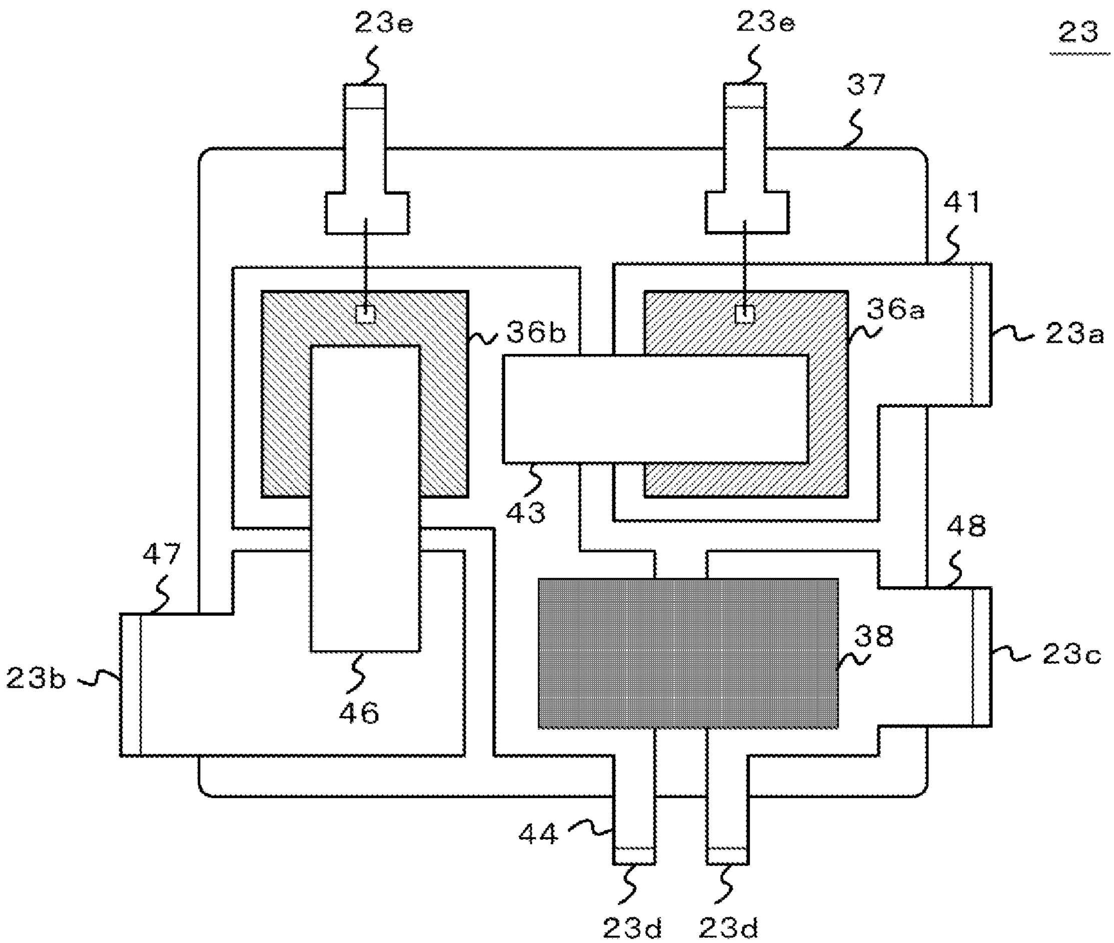


Fig. 8



ROTARY ELECTRIC MACHINE WITH POWER CONVERTER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to rotary electric machines and, more particularly, relates to a rotary electric machine mounted with a power converter.

2. Description of the Related Art

An alternator is a kind of a generator and is a device that converts mechanical kinetic energy transferred from an engine or the like into alternating current (AC) electrical energy. The alternator or the alternator serving also as a starter is mounted with a power converter on its main body. The power converter is equipped with power modules formed by molding a plurality of switching elements with insulating resin (for example, see Patent Document 1). The switching element includes a power transistor, a metal oxide semiconductor field effect transistor (MOSFET), an insulated gate bipolar transistor (IGBT), and the like.

Current detectors, each of which detects a phase current flowing through the switching element, are arranged in the power converter. The current detectors detect a plurality of phase currents; and ON/OFF of the switching elements mounted on terminals are performed by pulse width modulation (PWM) control. If this method is adopted for attaining a high output, a space for arranging the current detectors and a heat dissipation structure for cooling the generated heat of the current detectors are needed for the power converter. Joint between the power module and the current detector is made to constitute a circuit.

PATENT DOCUMENT

[Patent Document 1] International Unexamined Patent Publication No. WO 2012/169044 A1

BRIEF SUMMARY OF THE INVENTION

The present invention has been made to solve the above described problem, and an object of the present invention is to obtain a rotary electric machine equipped with a power converter in which a current detector is incorporated in a power module to improve productivity and to provide high heat dissipation performance and compactness.

According to the present invention, there is provided a rotary electric machine with a power converter, which includes: a stator that has stator windings; a rotor that has a rotor winding; a rotational position detecting sensor that outputs a rotational position signal of the rotor; a case that contains the stator and the rotor; a field module that is connected to the rotor winding; power modules, each of which is connected to each of the stator windings and has a current detector, a first switching element, and a second switching element; a heat sink that is fixed to the field module and the power modules; and a control substrate that outputs control signals to the field module and the power modules based on the rotational position signal from the rotational position detecting sensor. The first switching element is connected in series to the second switching element; and the current detector, the first switching element, and the second switching element are molded with insulating resin.

According to the rotary electric machine with the power converter according to the present invention, effects can be exhibited in that: the power converter is mounted with the current detector in the power module, whereby a heat dissipation structure similar to a heat dissipation structure of the switching elements can be adopted; further, the current detector is molded with insulating resin, thereby being less affected by outside environment; moreover, the current detector can be also mounted in the case of mounting the switching elements on the terminals, whereby productivity is improved; and additionally, the current detector can be mounted adjacent to upper and lower arms composed of the switching elements of the power module, whereby the power converter can be reduced in size.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. **1** is a longitudinal sectional view showing a rotary electric machine with a power converter according to embodiments of the present invention;

FIG. **2** is a view in which a power converter according to Embodiment 1 of the present invention is seen from the rear side;

FIG. **3** is an electrical circuit diagram of a rotary electric machine with the power converter according to Embodiment 1 of the present invention;

FIG. **4** is a configuration view of a power module according to Embodiment 1 of the present invention;

FIG. **5** is a sectional view of the power module according to Embodiment 1 of the present invention;

FIG. **6** is a configuration view of a power module according to Embodiment 2 of the present invention;

FIG. **7** is an internal wiring diagram of a power module according to Embodiment 3 of the present invention; and

FIG. **8** is a configuration view of the power module according to Embodiment 3 of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, embodiments of a rotary electric machine with a power converter according to the present invention will be described in detail with reference to drawings. Incidentally, the present invention is not limited to the following description, but can be appropriately changed without departing from the spirit or scope of the present invention.

Embodiment 1

FIG. **1** is a sectional view showing a rotary electric machine with a power converter according to embodiments of the present invention. A machine/electricity integral type rotary electric machine with a power converter **1** equipped with a rotary electric machine **2** and a power converter **3**. The rotary electric machine **2** includes an AC generator motor (motor generator). The rotary electric machine **2** is composed of a tubular stator **4**, a rotor **5** that is arranged inside the stator **4** and rotates with respect to the stator **4**, and a metallic case (support body) **6** that supports the stator **4** and the rotor **5**. The case **6** is divided into a front bracket **7** and a rear bracket **8**. The stator **4** is sandwiched by the front bracket **7** and the rear bracket **8**. The front bracket **7** and the rear bracket **8** are fastened by a plurality of fastening bolts **9**.

The stator **4** has a stator core **10** and stator windings (armature windings) **11**. The tubular stator core **10** is fixed to each of the front bracket **7** and the rear bracket **8**. The stator windings **11** are placed on the stator core **10**. The rotor **5** has a rotational shaft **12**, a rotor core **13**, and a rotor winding (field winding) **14**. The rotor core **13** is fixed at an intermediate portion of the rotational shaft **12**. The rotational shaft **12** is arranged on the axis line of the rotor **5** and passes through the front bracket **7** and the rear bracket **8**. The rotational shaft **12** is rotatably supported to each of the front bracket **7** and the rear bracket **8** via each of bearings **15**. The rotor winding (field winding) **14** is placed on the rotor core **13**.

An outer peripheral portion of the rotor core **13** is opposite to an inner peripheral portion of the stator **4**. The rotor core **13** is provided with a cooling fan for blowing air **16**, the cooling fan **16** being integrally rotated with the rotor **5**. A pulley **17** is fixed to an end on the front bracket side of the rotational shaft **12**. A transmission belt (not shown in the drawing) operatively connected with the rotational shaft of an engine is wound around the pulley **17**. A rotational position detecting sensor **18** that generates a rotational position signal in response to the rotational position of the rotational shaft **12** and a plurality of slip rings **19** electrically connected to the rotor winding **14** are placed on the rear side of the rotational shaft **12**. A brush holder **21** is placed on the rear bracket **8** with respect to each of the slip rings **19**. The brush holder **21** guides a brush **20** in a direction where the slip ring **19** comes into contact with or separates from the rotational shaft **12**.

The slip ring **19** is an annular conductive member that surrounds an outer peripheral portion of the rotational shaft **12**. The conductive brush **20** comes in contact with each of the slip rings **19**. A field current that makes the rotor **5** generate a magnetic field is supplied from the brushes **20** to the slip rings **19**. The brush holder **21** is provided with a pressing spring **22** that individually biases the brush **20** in a direction coming into contact with the slip ring **19**. The brush **20** is pressed to the slip ring **19** by the biasing force of the pressing spring **22**. When the rotor **5** rotates, the slip rings **19** slide with respect to the brushes **20**. The power converter **3** is supported by the rear bracket **8**.

A cover **39** formed of resin covers the power converter **3**. The power converter **3** includes power modules **23**, a field module **24**, a control substrate **25**, an external connection connector **27**, a heat sink **29**, a cooling fin **34**, a conductive busbar structure **31**, and the like. The power modules **23** and the field module **24** are connected to the conductive busbar structure **31**. The control substrate **25** which is for performing PWM control of the power modules **23** has a torus shape and is arranged on the upper sides of flat surface portions of the power modules on the side opposite to the heat sink **29**. The field module **24** and the power modules **23**, which are fixed to the heat sink **29**, are mounted on the cooling fin **34**. The conductive busbar structure **31** is manufactured by molding power input/output terminals **26**, N terminals **28**, and AC terminals **33**. The power modules **23** and the field module **24** are fixed to the heat sink **29** by using insulating adhesive.

FIG. **2** is a view in which the power converter **3** in Embodiment 1 of the present invention is seen from the rear side. Signal information from an external device (engine control unit or the like) is transferred to the power converter **3** via the external connection connector **27**. In order to understand easily, this drawing represents a state before the torus-shape control substrate **25** is attached. One field module **24** and six power modules **23** are shown in the drawing. Signal end terminals **18***a* of the rotational position detecting sensor **18** are connected to the control substrate **25**. The field module **24** has a battery end terminal **24***a*, a grounding end terminal **24***b*, field winding connection end terminals **24***c*, and signal end terminals **24***d*.

Each of the power modules **23** has a P end terminal **23***a*, an N end terminal **23***b*, an AC end terminal **23***c*, signal end terminals **23***d*, and signal end terminals **23***e*. The P end terminal **23***a* of the power module **23** is connected to the power input/output terminal **26**. The N end terminal **23***b* of the power module **23** is connected to the N terminal **28**. The AC end terminal **23***c* of the power module **23** is connected to the AC terminal **33**.

FIG. **3** is an electrical circuit diagram of the rotary electric machine according to Embodiment 1 of the present invention. The operation of the power converter **3** will be described with reference to this drawing. The power converter **3** is electrically connected to the stator windings **11**. Six power modules **23** and one field module **24** are shown in the drawing. Each of the power modules **23** shows a circuit for one phase of a three phase bridge circuit that constitutes a circuit of the power converter **3**. The power module **23** is manufactured by molding a pair of elements in which two switching elements **36** for carrying a stator current are connected in series and a current detector **38**.

The AC end terminal **23***c* of the power module **23** is AC input/output to be connected to the stator winding **11**. The signal end terminal **23***d* is connected to a contact point between a drain of a first switching element **36***a* and a source of a second switching element **36***b*. The signal end terminal **23***e* of the power module **23** is connected to a gate electrode of the switching element **36**. Two switching elements **36** are connected in series. The switching element **36** on the right side corresponds to an upper arm; and the switching element **36** on the left side corresponds to a lower arm. A shunt resistance is preferable to be used for the current detector **38**.

The field module **24** is manufactured by molding a plurality of switching elements **32** that carry a field current. In this case, the field module **24** is equipped with three switching elements **32**. The field module **24** adjusts power from a battery **30** and supplies to the rotor winding **14** as the field current based on control signals from the control substrate **25**.

Signal end terminals **18***a* of the rotational position detecting sensor **18** are connected to substrate end terminals **25***a* of the control substrate **25**. The signal end terminals **24***d* of the field module **24** are connected to substrate end terminals **25***b* of the control substrate **25**. The signal end terminals **23***d* and the signal end terminals **23***e* of the power modules **23** are connected to substrate end terminals **25***c* of the control substrate **25**. Signal end terminals of the external connection connector **27** are connected to substrate end terminals **25***d* of the control substrate **25**. The control substrate **25** outputs the control signals to the field module **24** and the power modules **23** based on the rotational position signal of the rotor **5** from the rotational position detecting sensor **18** and signal information from the external device (engine control unit or the like) transferred via the external connection connector **27**.

Direct current (DC) power from the battery **30** is supplied to each of the power modules **23** and the field module **24** at the time of starting up the engine. The field module **24** adjusts the DC power from the battery **30** into the field current by the control of the control substrate **25**. The field current from the field module **24** is supplied to the rotor winding **14** via the brushes **20** and the slip rings **19**. This generates a DC magnetic field in the rotor **5**. The control substrate **25** makes the power modules **23** perform switching operation by the PWM control from a plurality of phase current values detected by the current detectors **38**. This converts the DC power from the battery **30** into AC power.

The AC power converted by the power modules **23** is supplied to the stator windings **11**. A rotating magnetic field is generated in the stator **4** to rotate the rotor **5**. The pulley **17** is rotated by the rotation of the rotor **5** to start up the engine. After starting up the engine, rotative power from the engine is transferred to the pulley **17**. This rotates the rotor **5** and thus AC power is induced in the stator windings **11**. At this time, the power modules **23** perform switching operation by the PWM control of the control substrate **25** from the plurality of phase current values detected by the current detectors **38**. This converts the AC power induced in the stator windings **11** into

DC power. After that, the DC power from the power modules **23** is charged in the battery **30**.

Next, the mounting configuration of the power module **23** in Embodiment 1 will be described by using FIG. **4**. In the power converter **3**, the power module **23** corresponds to the circuit for one phase of the three phase bridge circuit. The first switching element **36***a* is connected in series to the second switching element **36***b*. The gate electrode of the first switching element **36***a* and the gate electrode of the second switching element **36***b* are each connected to each of the signal end terminals **23***e*. The first switching element **36***a* is arranged on a first terminal **41** and a lower surface electrode of the first switching element **36***a* is joined to the first terminal **41** via solder.

One end of a first internal lead **43** is joined to an upper surface electrode of the first switching element **36***a* via solder and the other end of the first internal lead **43** is joined to a second terminal **44** via solder (constituting the upper arm). The second switching element **36***b* is arranged on the second terminal **44** and a lower surface electrode of the second switching element **36***b* is joined to the second terminal **44** via solder. One end of a second internal lead **46** is joined to an upper surface electrode of the second switching element **36***b* via solder. The other end of the second internal lead **46** is joined to a third terminal **47** via solder (constituting the lower arm).

One end of the current detector **38** is joined on the third terminal **47** via solder and the other end of the current detector **38** is joined to a fourth terminal **48** via solder. The power converter **3** is molded by using insulating resin **37** such as silicone resin having a linear expansion coefficient near that of the terminal. The periphery of a joint portion of the current detector **38** is solidified with the insulating resin **37**; and therefore, the current detector **38** is less likely to be affected by outside environment and, moreover, can reduce stress due to repeated thermal expansion and contraction to extend duration of life.

FIG. **5** shows a sectional view of the power module. The power module **23** is fixed to the heat sink **29** by using, for example, silicone insulating adhesive **50**. The heat sink **29** is attached to the cooling fin **34** by screws or the like. The second terminal **44**, the third terminal **47**, and the fourth terminal **48** are arranged in a lowermost layer. Similarly, the first terminal **41** and the signal end terminals **23***e* are also arranged in the lowermost layer. These members arranged in the lowermost layer are exposed from the insulating resin **37** and thus can be directly bonded to the heat sink **29** with the silicone insulating adhesive **50**. The current detector **38** and the second switching element **36***b* (and the first switching element **36***a*) are arranged in a second layer.

According to this Embodiment 1, the power module **23** is arranged on the heat sink **29**; and therefore, the generated heat of the current detector **38** can be dissipated from the heat sink via the terminals as in the switching elements. Furthermore, the joint of the current detector **38** and the terminals is the same soldering as the joint of the switching elements and the terminals; and therefore, mounting can be made simultaneously by one process. Besides, one of electrodes of the current detector **38** is directly mounted on the third terminal **47**; and therefore, the power converter can be reduced beyond an increase in size of the power module **23**.

Embodiment 2

The mounting configuration of a power module **23** in Embodiment 2 will be described by using FIG. **6**. In Embodiment 1, the P end terminal **23***a* and the N end terminal **23***b* of the power module **23** are led out from different edges of the insulating resin **37**; however, in Embodiment 2, a P end terminal **23***a* and an N end terminal **23***b* are led out from the same edge. This configuration can provide the shortest circuit path from the P end terminal to the N terminal; and therefore, inductance can be reduced.

Embodiment 3

FIG. **7** shows an electrical circuit diagram of a power module **23** showing Embodiment 3. In Embodiment 1 and Embodiment 2, the current detector **38** is arranged between the lower arm and the N end terminal **23***b*; however, in this case, a current detector **38** is arranged between a midpoint of upper and lower arms and an AC end terminal **23***c*. This configuration can monitor a current value flowing through the upper arm (a first switching element **36***a*) and the lower arm (a second switching element **36***b*), respectively; and therefore, it becomes possible to attain more highly accurate control in a power converter.

FIG. **8** shows the mounting configuration of a power module **23** in Embodiment 3. In Embodiment 3, a P end terminal **23***a* and the AC end terminal **23***c* are led out from the same edge. This configuration can provide the shortest circuit path from the P end terminal to the AC end terminal **23***c*; and therefore, inductance can be reduced.

Incidentally, the present invention can freely combine the embodiments and appropriately change or omit the respective embodiments, within the scope of the present invention.

What is claimed is:

1. A rotary electric machine with a power converter, comprising:

a stator that has stator windings;

a rotor that has a rotor winding;

a rotational position detecting sensor that outputs a rotational position signal of said rotor;

a case that contains said stator and said rotor;

a field module that is connected to said rotor winding;

power modules, each of which is connected to each of said stator windings and has a current detector, a first switching element, and a second switching element;

a heat sink that is fixed to said field module and said power modules; and

a control substrate that outputs control signals to said field module and said power modules based on the rotational position signal from said rotational position detecting sensor,

wherein said first switching element is connected in series to said second switching element;

said current detector, said first switching element, and said second switching element are molded with insulating resin; and

said current detector is attached in series to said second switching element, and

further wherein said power module includes:

a first terminal that is joined to a lower surface electrode of said first switching element;

a second terminal that is joined to a lower surface electrode of said second switching element;

a third terminal that is joined to one end of said current detector; and

a fourth terminal that is joined to the other end of said current detector; and

said first terminal, said second terminal, said third terminal and said fourth terminal are directly bonded to said heat sink.

2. The rotary electric machine with the power converter according to claim **1**,

wherein an output end terminal of said second terminal and an output end terminal of said fourth terminal are led out from the same side edge of said insulating resin.

3. The rotary electric machine with the power converter according to claim 1,

wherein an output end terminal of said first terminal and an output end terminal of said fourth terminal are led out from the same side edge of said insulating resin.

4. A rotary electric machine with a power converter, comprising:

a stator that has stator windings;

a rotor that has a rotor winding;

a rotational position detecting sensor that outputs a rotational position signal of said rotor;

a case that contains said stator and said rotor;

a field module that is connected to said rotor winding;

power modules, each of which is connected to each of said stator windings and has a current detector, a first switching element, and a second switching element;

a heat sink that is fixed to said field module and said power modules; and

a control substrate that outputs control signals to said field module and said power modules based on the rotational position signal from said rotational position detecting sensor,

wherein said first switching element is connected in series to said second switching element; and

said current detector, said first switching element, and said second switching element are molded with insulating resin; and

one end of said current detector is attached between said first switching element and said second switching element, and

further wherein said power module includes:

a first terminal that is joined to a lower surface electrode of said first switching element;

a second terminal that is connected to a lower surface electrode of said second switching element and one end of said current detector;

a third terminal that is connected to a lead joined to an upper surface electrode of said second switching element; and

a fourth terminal that is connected to the other end of said current detector and;

said first terminal, said second terminal, said third terminal and said fourth terminal are directly bonded to said heat sink.

5. The rotary electric machine with the power converter according to claim 4,

wherein an output end terminal of said first terminal and an output end terminal of said fourth terminal are led out from the same side edge of said insulating resin.

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